The Intracanal Diffusion of Camphorated Para-mono-chlorophenol in Endodontics: An Autoradiographic Study

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THE INTRACANAL DIFFUSION OF CAMPHORATED PARA-MONO-CHLOROPHENOL IN ENDODONTICS:
AN AUTORADIOGRAPHIC STUDY

BY
GERALD R. HEIMAN, D.D.S.

A Thesis Submitted to the Faculty of the Graduate School of Loyola University in Partial Fulfillment of the Requirements for the Degree of Master of Science

JUNE 1971

Library--Loyola University Medical Center
DEDICATION

To my loving wife Catherine, whose devotion, loyalty and patience are unending, I dedicate this thesis.
ACKNOWLEDGMENTS

My sincere gratitude and appreciation to the following:

To John V. Madonia, D.D.S., Ph.D., Chairman, Department of Microbiology, my advisor, for his guidance in preparing this thesis.

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To my parents for their love, understanding, encouragement and faith throughout the years.

To Mrs. Mickevicius and Mrs. Tumosa for their help in the laboratory.
AUTOBIOGRAPHY

Gerald R. Heiman was born in Chicago, Illinois, on October 5, 1942. There he attended St. Priscilla Elementary School and St. Patrick High School.

In September, 1960, he entered St. Mary's College in Winona, Minnesota, and in 1962 he transferred to Loyola University of Chicago. He was accepted to Loyola University School of Dentistry in 1963 and graduated with the degree of Doctor of Dental Surgery in June of 1967.

After graduation from dental school he entered the United States Navy Dental Corps as a commissioned officer and was stationed in San Francisco California, for two years. He then returned to Loyola University School of Dentistry, Chicago, Illinois, in 1969 to pursue a two-year graduate program in the Department of Oral Biology leading to the degree of Master of Science and a postgraduate certificate in Endodontics.

The author is married and has two daughters.
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CHAPTER 1

INTRODUCTION

One of the most commonly used intracanal medicaments in endodontics has been camphorated para-mono-chlorophenol. This medicament was introduced by Dr. Otto Wolkoff in 1891 as a eutectic solution of 35% para-mono-chlorophenol in a camphor vehicle. As with many other drugs used in endodontics, investigations have been confined to its antimicrobial spectrum and toxicity.

The dentinal tubules of teeth which are undergoing endodontic treatment can and do harbor many different micro-organisms. As endodontists we should, therefore, be concerned not only with the spectrum and toxicity but also with the ability of our intracanal medicaments to penetrate into these infected dentinal tubules in order for it to be effective against the micro-organisms.

It is the purpose of this research to determine, by means of tritium labeling, the ability of camphorated para-mono-chlorophenol to penetrate into the dentinal tubules of endodontically-treated teeth.
CHAPTER 2

LITERATURE REVIEW

A. Dye Penetration Studies

Harlan (1891) recommended root canal medicaments which would penetrate into the dentin. Compounds such as phenol, zinc chloride, sulfuric acid and creosote were felt to be self-limiting due to their protein coagulation.

Coolidge (1929) agreed with Harlan (1891) in reporting that drugs causing protein coagulation have poor dentin penetration and that low surface tension is of value only if the compound does not precipitate protein.

Buest (1931) found that dye penetration was greater in the dentin of young teeth than old teeth. He used fuchsin stain and examined ground sections under transmitted light.

In 1933, Fish completed one of the classic dentin penetration studies using methylene blue. Fish packed solid methylene blue dye into the pulp chamber of extracted teeth, moistened the dye with saliva and closed the chamber with wax. The teeth were incubated at 37°C. in a moist chamber for 24 hours. He then prepared ground sections and found that the stain penetrated the dentin to varying degrees. In older teeth the peripheral dentin
in the root was at times hypercalcified. A translucent dentin seemed to occlude the ends of the tubules.

Bodecker and Lefkowitz (1937) reported that dentin permeability was reduced by maturation, aging, abrasion and caries. Permeability, however, was temporarily increased after pulp removal.

B. Radioactive Isotope Studies

One of the first papers published on the use of radioactive isotopes in teeth was that of Hevesy, Holst and Krogh in 1937. They showed that the highest degree of $P^{32}$ absorption from the blood was in the circumpulpal area. A similar experiment in 1939, by Manly and Bale also used $P^{32}$. They fed rats 120 mg. of $P^{32}$ in a single dose daily by a stomach tube. At various intervals after feedings the animals were sacrificed. The rat incisors were divided into tips, middles and roots. The samples were dissolved in 2 cc. of dilute hydrochloric acid and their radioactivity measured with a Geiger-Muller counter. They showed that teeth without pulps take up $P^{32}$ faster than intact teeth and that tips of roots show high activity measurements.

In 1941, Sognnaes and Volker fed animals with $P^{32}$ by way of a stomach tube. The animals were sacrificed and the teeth cleaned, dried and separated. Under a microscope the enamel was ground off
and the specimens examined with a Geiger-Müller counter. The dentin was also separated into apical and coronal sections and the dentin permeability of P\textsuperscript{32} varied with different morphological and pathological varieties of dentin.

Gilda and McCauley (1943) found that devitalization of dogs' teeth lowered the uptake of systemic P\textsuperscript{32}. The pulps were extripated and the canals filled with zinc oxide and eugenol. The animals were sacrificed 36 hours after intravenous injection of P\textsuperscript{32}. The sectioned teeth were then autoradiographed.

Amler and Bevelander (1945) agreed with Bodecker (1943) that the absorption of P\textsuperscript{32} is dependent upon the structure of dentin. In comparing their results with those of Van Huysen, Hodge and Warren (1937) who measured the density of dentin, Amler and Bevelander found that P\textsuperscript{32} absorption decreases as density increases. They also showed that dentin absorbs P\textsuperscript{32} in the same order under \textit{in vivo} and \textit{in vitro} conditions.

Amler (1948) and Amler and Bevelander (1951) continued with their studies of P\textsuperscript{32} penetration into dentin in the presence or absence of various medicaments. They prepared cavities in canine and molar teeth of dogs. Before applying P\textsuperscript{32} \([\text{Na}_2(\text{HPO}_4)_4]\) the cavities were treated with either phenol; phenol followed by alcohol; fluorine; silver nitrate followed by eugenol; cavity
varnish; or zinc oxyphosphate cement and sealed with silver amalgam. The amalgam fillings were removed at 7 days, 14 days or 70 days and the $P_{32}^3$ was placed in the cavity and sealed again with silver amalgam. The animals were sacrificed and thin ground sections were prepared and autoradiographed. The investigators reported that all of the medicaments except zinc oxyphosphate cement increased the permeability of the dentin. The zinc oxyphosphate cement served as an impervious barrier to $P_{32}^3$. These results were also confirmed by Martin (1951) who used a direct tissue autoradiography technique on human teeth. He sectioned the teeth and covered the sections with a very fine grain film emulsion which remained permanently in contact with the tooth exposing the emulsion to the isotope. The emulsion was then developed while still in contact with the tooth.

In 1960, Marshall, Massler and Dute concentrated for the first time on the effects of medicaments used in endodontic procedures on the permeability of dentin. The root canals of 253 freshly extracted teeth were reamed and filed and the apices sealed with sticky wax. Various solutions were placed in the canal either alone or in combination for a specific time period. The canal was then dried and one of the isotope solutions ($P_{32}^3$, $Na^{22}$, $I^{131}$, or $S^{35}$) was placed in the canal. The teeth were stored for 24 hours at $37^\circ C$ and 100% humidity. Ground sections were prepared
and autoradiographed. They concluded that silver nitrate alone or hydrogen peroxide and sodium hypochlorite solutions used alternately produced significant increased dentin permeability, whereas EDTA (ethylene-diamine tetra acetic acid), hydrogen peroxide alone, sodium hypochlorite alone, silver nitrate and formalin, formalin alone, eugenol alone and sodium bicarbonate alone showed no significant changes in dentin permeability. They further concluded $^{35}S$ was the superior radioactive label.

C. Medicament Penetration Studies

1. Non-Radiolabeled Medicament Studies

It was shown by Shuttleworth in 1950 that penicillin diffused from the root canal through both the dentin and cementum and beyond into the surrounding media. He divided freshly extracted teeth into four groups: (1) whole teeth; (2) teeth with their crowns removed; (3) those cut at mid-root; (4) teeth that had the apices cut off. Each of the teeth had the pulps removed and paper points with penicillin placed in the canals. The teeth were sealed at both ends and placed on blood agar plates inoculated with *Staphylococcus aureus*. A significant zone of inhibition around the teeth was reported.
Stamps (1953) stated that phenol could penetrate to a depth of 2 mm. in dentin. In 1956, Coolidge and Kesel reported that parachlorophenol as described by Wolkoff in 1891 would penetrate deeper than phenol because it does not coagulate protein or cauterize tissue.

The research of Stewart, Kapsimalas and Rappaport in 1969 showed that root canals prepared with a combination of ethylene-diamine tetra acetic acid (EDTA) and urea peroxide were more penetrable by a 2% aniline dye than root canals prepared with EDTA alone.

2. Radiolabeled Medicament Studies

Wainwright and Lemoine (1950) employed radioactive urea labeled with C\(^{14}\) in their study of urea penetration in human teeth. Freshly extracted teeth were washed, pumiced, washed again, dried, washed with benzene, dried and mounted in wax. After 10 minutes the radioactive urea was applied to the surface of the teeth and allowed to dry. The teeth were then embedded in clear plastic and ground sections were prepared. They used a Tracerlab mica window tube and laboratory monitor with a counting rate meter to measure radioactivity. Autoradiographs were also prepared which showed the greatest penetration of urea near the gingival line and near occlusal fissures of the teeth.
Penicillin labeled with $^{35}$S was used in 1955 by Wach, et al, to study dentinal penetration of the penicillin. Fourteen freshly extracted human teeth were each placed in an individual bottle in a moist atmosphere and stored in a refrigerator for not more than 24 hours. The teeth were divided into four groups. Group one contained teeth with carious pulp exposures. These teeth had $^{35}$S labeled penicillin applied by placing a saturated cotton pellet in the carious lesion. The other three groups had the pulps removed from the teeth and minimal enlargements of the canals. Group two had paper points containing 5,000 units of penicillin inserted in the canal without sealing it. The third group was handled the same as the second but was sealed. The fourth group had the isotope incorporated into the powder portion of a root canal filling material mixed to a paste, and the canal filled with the paste. All the teeth were stored in a moist atmosphere for an arbitrary period of time and then subjected to autoradiographic and chromatographic evaluations. They found that the uptake of $^{35}$S labeled penicillin in dentin was variable; little or no penicillin penetrated the dentin in the apical third; there was no penetration through intact enamel or cementum.

In 1964, Hampson and Atkinson studied the effects of centrimides, chlorhexidine solution and hypochlorite on dentin
permeability. The pulps of freshly extracted teeth were extripated and the canals enlarged. Paper points containing the medicaments were placed in the canals and radioactive solutions of either iodine or sulphur were added using an Agla micrometer syringe. The teeth were sectioned longitudinally through the root canals and the sections placed on fast dental X-ray film for autoradiographs. The results were analyzed by placing the films in a photographic enlarger and projecting an image of the tooth on squared graph paper. They found the apical dentin to be impermeable while the cervical and mid-root dentin showed variable degrees of permeability. Permeability was increased by chloramine cetrimide and chlorhexidene.

Nicholson, Stark, Nguyen and Scott (1968) utilized $^{45}$Ca labeled EDTA in their penetration study of pulpless monkey and human teeth. After inserting the labeled EDTA, ground sections were prepared and autoradiographed. They concluded that the self-limiting properties of the compound appeared questionable.

D. Tritium Labeled Studies

In recent years tritium labeling services have been made readily available to researchers through commercial suppliers
(Evans, 1968). Feinendfgen (1967) noted that tritium was the isotope of his choice because of its versatility and the relative ease of labeling compounds with it. Because tritium is a low energy beta emitter, the label is localized and prevents excessive scatter to and false labeling of tissue components distant from the actual labeled area (Zach, 1969). According to Hughes (1958) a beta-ray will travel a maximum distance of six microns in tissue and half of the particles will travel less than one micron. Consequently, the majority of the activated silver grains in an autoradiogram will lie within one micron of their source.

Tritiated thymidine has been used for the evaluation of cellular synthesis in studies of general wound healing (Montagna and Billingham, 1964), skeletal repair (Tonna, 1966), gingival healing (Engler et al, 1966; Ramfjord et al, 1966; and Stahl et al, 1968); and more recently pulp and periapical responses to injury (Zach et al, 1969; Stahl et al, 1969).

In 1970 for the first time Avny used a tritiated intracanal medicament to study its penetration into dentin. He used tritium labeled parachlorophenol in a 2% aqueous solution and sealed it in freshly extracted human teeth for 48 hours. Serial sections were prepared and autoradiographed. The results indicated that the medicament penetrated to the cemento-dentinal junction.
CHAPTER 3

MATERIALS AND METHODS

For this study camphor\(^1\) and para-mono-chlorophenol\(^2\) were supplied to a commercial laboratory\(^3\) to be radiolabeled and compounded. The catalytic ion exchange method was used to prepare the tritium labeled para-mono-chlorophenol with a specific activity of 5 mCi/millimole. A eutectic solution of 35% tritium labeled para-mono-chlorophenol and 65% camphor was then prepared.

Sixteen freshly extracted human intact maxillary teeth were obtained from the Oral Surgery Department of Loyola University School of Dentistry and placed in sterile saline. These teeth were immediately randomly divided into four equal groups and prepared as follows:

Group I: Control Group

Access cavity preparations were made with a high speed tapered fissure #701 carbide bur and a #4 slow speed long shank round carbide bur. A fine-fine barbed broach\(^4\) was then used to remove the pulp tissue from the root canal. The root canal was completely cleansed.

---

1. Eastman Organic Chemical; Rochester, New York.
2. Eastman Organic Chemical; Rochester, New York.
and shaped to within one millimeter of the apex by using standardized "K" type style "B" stainless files. The instrumentation (cleansing and shaping) was considered to be complete when clean white dentinal shavings were evident on the instruments. Sodium hypochlorite was used to keep the root canal flooded during instrumentation; while sodium hypochlorite and hydrogen peroxide were the final irrigating solutions. Cotton pellets (#2) and prepackaged sterile medium paper points were used to dry the pulp chamber and root canal respectively.

A #2 dry cotton pellet was then placed in the pulp chamber. The coronal access cavity was sealed with cavit and the apex was sealed with green stick impression compound. The teeth were stored separately in 100% humidity at 98°F. for 48 hours.

Group II:

The teeth in the second group were prepared in exactly the same manner as those in the Control Group I except that a medium paper point containing radiolabeled camphorated para-mono-chlorophenol was sealed in the pulp canal and no cotton pellet was left in the pulp chamber.

5. Union Broach; Long Island, New York.
6. Zonite; Chemway Corp.; Wayne, New Jersey.
8. Johnson & Johnson Products; New Brunswick, New Jersey.
Group III:

In Group III the preparation of the teeth differed in that the cleansing and shaping was confined to the buccal surfaces in order to leave some pulpal tissue on the lingual wall. A #2 cotton pellet with radiolabeled camphorated para-mono-chlorophenol was sealed in the tooth.

Group IV:

The teeth in Group IV were prepared in exactly the same manner as those in Control Group I except that the #2 cotton pellet sealed in the pulp chamber contained radiolabeled camphorated para-mono-chlorophenol.

All of the teeth were handled individually with rubber gloves to prevent cross-contamination. Care was taken to prevent excess camphorated para-mono-chlorophenol from flowing on to the external surface of the teeth and all instruments were thoroughly washed and scrubbed before entering each tooth.

After 48 hours in 100% humidity all of the teeth were placed in separate decalcifying solutions containing 50% of 88% formic acid and 50% of 20% sodium citrate (Preece, 1965). The teeth were kept in this solution for twelve days. All four groups of teeth were bisected bucco-lingually using razor blades. A one-blade per tooth procedure was followed to prevent contamination.
The teeth were then sealed in paraffin and central sections with a thickness of 4 microns were made. Autoradiographs were produced by coating the sections with radiographic emulsion and placing them in a light tight box for four days. After developing and fixing, the sections were stained with nuclear fast red Indigo-Carmine dye and picric acid. The specimens were then examined microscopically and the silver grains produced by the radiolabeled camphorated para-mono-chlorophenol were counted with the aid of an automatic hand counter. A 50 micron square grid was superimposed over the grains to facilitate counting. All counting was done under oil emersion (1000X). Ten random background counts were made in areas free of specimen on each slide examined. This was necessary to establish counts above background on each tooth section.

Each section in all groups was divided into apical 1/3, middle 1/3, and coronal 1/3 areas. In Groups II, III, and IV the grid was superimposed over the dentin directly against the pulpal wall. The grains within the grid were counted and recorded and the grid was moved one grid width at a time away from the pulp wall and perpendicular to it until no significant counts above background were recorded. This procedure was repeated ten times at random points along the pulp wall in each 1/3 of each section.

In Group I, grain counts were started at the pulpal wall and moved one grid width at a time until ten counts were made. This was
done at six random points along the pulpal wall in each 1/3 of each section.

The mean counts above background were determined for the various fields in each group. Statistical analysis of the results was carried out using the t-test for comparing two means.
CHAPTER 4

RESULTS

Statistical analysis using the t-test to compare mean grain counts above background of Groups I and II are shown in Table 1. In the coronal 1/3 of the teeth in Group II (teeth with paper points containing the tritium labeled medicament sealed in) there was a significant (P = 0.01) penetration of labeled camphorated para-mono-chlorophenol 0.20 mm. from the pulpal wall. In the middle 1/3, significant penetration was noted 0.25 mm. from the pulpal wall. Significant penetration was minimal in the apical 1/3 where the radio-labeled medicament traveled only 0.05 mm. from the pulpal wall. The greatest penetration then in Group II was in the middle 1/3.

Turning to Group III (teeth in which the cleansing and shaping was confined to the buccal surface of the canal and medicament sealed on a cotton pellet) and its statistical comparison with the Control Group I (Table 2), it can be seen that the greatest penetration was in the coronal 1/3. No significant penetration was seen in the apical 1/3 while penetration to 0.05 mm. was seen in the middle 1/3 and to 0.40 mm. in the coronal 1/3. All counting was confined to the partially cleansed lingual surface.

Table 3 shows a significant penetration in the coronal 1/3 of teeth in Group IV (those cleansed and shaped with placement of
radiolabeled camphorated para-mono-chlorophenol on a cotton pellet) to a depth of 0.25 mm. from the pulpal wall. In the middle 1/3 penetration was only to 0.15 mm. Again, in the apical 1/3 penetration was limited to 0.05 mm. from the pulpal wall.

It was also observed in all sections in the experimental groups that there was an extremely high concentration of activated grains in the pulp chamber or canal immediately adjacent to the cotton pellet or paper point.

Figures 2 and 3 show the distribution of tritium labeled camphorated para-mono-chlorophenol in the various areas of the teeth in Groups I through IV.
CHAPTER 5

DISCUSSION

It is well established that bacteria in a tooth are rarely confined to one area of a tooth such as the pulp chamber or the pulp canal. Instead they are found throughout the whole tooth and especially in the dentinal tubules (Gurney, 1963).

Since the natural defense mechanisms of the body have been destroyed inside a tooth undergoing endodontic treatment, microorganisms in these teeth must be brought under control by some other means. Large numbers of microorganisms can be removed through biomechanical preparation. Chemotherapeutic agents, however, are required to eliminate the remaining microorganisms.

The minimum requirements of an ideal root canal medication are: (1) that it be germicidal to most organisms; (2) that it has deep penetration; (3) that it exhibits rapid effectiveness; and (4) that it is effective in the presence of organic matter (Sommer, Ostrander and Crowley, 1961).

Camphorated para-mono-chlorophenol has been considered clinically as a highly effective antimicrobial agent (Ostrander, 1958). Little experimental evidence, however, has been presented to date to classify camphorated para-mono-chlorophenol as an ideal root canal medicament.
This study was concerned only with the second minimum requirement of an ideal intracanal medicament, the ability to penetrate into dentin.

Tritium was used in this study because of the ease with which compounds can be labeled with it. It has a convenient half life and is a low energy beta emitter which gives an accurate relation of silver grains to labeled material.

Thin sections were essential in order to accurately measure the exact depth of penetration into the dentinal tubules. Decalcified sections were used rather than ground sections because of the problems encountered in a similar study by Avny in 1970. He found that in preparing thin ground sections there was a scattering of radioactive material over the surface of the tooth which gave inaccurate and false results.

It is apparent from Tables 1 through 3 that the greatest penetration of camphorated para-mono-chlorophenol in the coronal 1/3 occurs in Group III where the medicament was placed on a cotton pellet in the chamber and sealed in. In the middle 1/3 the greatest penetration was in Group II where the medicament was placed on a paper point in the canal. Penetration in the middle 1/3 appeared to be greatly reduced by the pulpal tissue along the lingual wall in Group III as compared to Group IV, both of which had radiolabeled CPC on a cotton pellet in the chamber. The poorest penetration was in the apical 1/3 in all
groups. The teeth in the Control Group showed grain counts very similar to background (insignificant difference at $P = 0.50$) and equally dispersed throughout the dentin thus allowing the comparison of mean counts above background of the Control Group and each of the other groups.

From the results it would seem that camphorated para-mono-chlorophenol stays predominantly in the area where it is placed and if used, would be most effectively placed on a paper point or cotton pellet in intimate contact with the pulpal wall along its entire length. The idea held by many practitioners, that because this medicament is highly volatile, it penetrates rapidly and deeply into all the dentinal tubules, appears to be in great error.

The antimicrobial activity of camphorated para-mono-chlorophenol has been reported to be due solely to the para-mono-chlorophenol while the camphor serves merely as a vehicle. While camphor possesses no antiseptic value, it does have a slight anodyne effect (Sommer, Ostrander and Crowley, 1961). From this study it would appear that camphor also acts as a reservoir releasing the para-mono-chlorophenol very slowly.

The results of Harrison's 1969 experiments indicated:

1) CPC (camphorated para-mono-chlorophenol) is highly toxic, 2) a reduced parachlorophenol concentration in a vehicle of water is far less toxic than
CPC and 3) parachlorophenol is an effective antimicrobial agent in extremely small concentrations in aqueous solution against a variety of microorganisms commonly found in the root canal."

Avny's study in 1970 indicated that parachlorophenol in a vehicle of water has deep penetration capability and that the use of either a paper point or a cotton pellet to carry the medicament into the tooth resulted in penetration throughout the dentin in the apical, middle and coronal 1/3's to the cemento-dentinal junction, a distance at least 7 to 10 times greater than the present study.

Considering the advantages of 2% aqueous parachlorophenol as pointed out by Harrison and Avny in their studies and the failure of camphorated para-mono-chlorophenol to penetrate beyond a maximum of 0.40 mm. into the dentin in the present study, perhaps the choice of one of these two intracanal medicaments in endodontic therapy should be re-evaluated. Since camphor serves only as a vehicle for the para-mono-chlorophenol and CPC is highly toxic to the tissues, it would seem that para-mono-chlorophenol in an aqueous vehicle would be preferred.
CHAPTER 6

SUMMARY

A study of the ability of camphorated para-mono-chlorophenol to penetrate into the dentinal tubules of endodontically-treated teeth was conducted using tritium labeling. Autoradiographic evidence indicated that this intracanal medicament placed on cotton pellets and paper points penetrated a maximum of 0.40 mm. into the dentin of the coronal 1/3, 0.25 mm. into the dentin of the middle 1/3, and 0.05 mm. into the dentin of the apical 1/3.
CHAPTER 7

BIBLIOGRAPHY


CHAPTER 8

APPENDIX
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<td>0.10</td>
<td>1.35</td>
<td>0.93</td>
<td>0.47</td>
<td>-</td>
</tr>
</tbody>
</table>

* 1 Grid = 50 μ or 0.05 mm.
** To be statistically significant at P = 0.01, t must be equal to or greater than 2.39.
### TABLE 2

**PENETRATION INTO DENTIN OF TRITIUM LABELED CAMPHORATED PARAMONOCHLOROPHENOL PLACED ON A COTTON PELLET**

**PARTIALLY CLEANSED TEETH**

<table>
<thead>
<tr>
<th>Grids* from Pulpal Wall</th>
<th>Distance from Pulpal Wall (mm)</th>
<th>Mean Count above Background Group III</th>
<th>Mean Count above Background Group I (Control)</th>
<th>t</th>
<th>Significant at P = 0.01**</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coronal 1/3</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1</td>
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<td>6.44</td>
<td>+</td>
</tr>
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</tr>
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</tr>
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<td>+</td>
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</tr>
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<td>3.20</td>
<td>+</td>
</tr>
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<td>7</td>
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<td>5.55</td>
<td>-0.39</td>
<td>3.39</td>
<td>+</td>
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<td>1.28</td>
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<td><strong>Middle 1/3</strong></td>
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<td>0.06</td>
<td>3.03</td>
<td>+</td>
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<td>0.25</td>
<td>-1.04</td>
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</tr>
<tr>
<td><strong>Apical 1/3</strong></td>
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<td>-0.20</td>
<td>-0.53</td>
<td>0.46</td>
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</tr>
</tbody>
</table>

* 1 Grid = 50 μ or 0.05 mm.

**To be statistically significant at P = 0.01, t must be equal to or greater than 2.39.
TABLE 3

PENETRATION INTO DENTIN OF TRITIUM LABELED CAMPHORATED PARAMONOCHLOROPHENOL PLACED ON A COTTON PELLET

<table>
<thead>
<tr>
<th>Grids* from Pulpal Wall</th>
<th>Distance from Pulpal Wall (mm.)</th>
<th>Mean Count above Background Group IV (Control)</th>
<th>t</th>
<th>Significant at P = 0.01**</th>
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</thead>
<tbody>
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<td>Mean Count above Background Group IV (Control)</td>
<td>t</td>
<td>Significant at P = 0.01**</td>
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<td></td>
</tr>
<tr>
<td>Coronal 1/3</td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>0.15</td>
<td>12.45</td>
<td>0.38</td>
<td>5.35</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>+</td>
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<td>0.70</td>
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<td>1.65</td>
<td>-0.39</td>
<td>1.87</td>
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<tr>
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<td></td>
<td>-</td>
</tr>
<tr>
<td>Middle 1/3</td>
<td></td>
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<td></td>
</tr>
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<td>11.25</td>
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<td>4.80</td>
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<tr>
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<td>-</td>
</tr>
</tbody>
</table>

* 1 Grid = 50 μm. or 0.05 mm.

** To be statistically significant at P = 0.01, t must be equal to or greater than 2.39.
Figure 1: Appearance of decalcified sections.
Figure 2: Distribution of Tritium Labeled Camphorated Paramonochlorophenol in Coronal 1/3 of Teeth in Groups I through IV.

- Group I (Control)
- Group II
- Group III
- Group IV

1 Grid = 50 μ, or .05 mm.
Figure 3: Distribution of Tritium Labeled Camphorated Paramonochlorophenol in Middle 1/3 of Teeth in Groups I through IV.

☐ Group I (Control)
○ Group II
▲ Group III
● Group IV
1 Grid = 50 μ or .05 mm.
Figure 4: Original Magnification 200X
Control Group I. Point
Group II - Pulp Canal.
Figure 5: Original Magnification 450X
Radioactive Paper Point
Group II - Pulp Canal.
Figure 6: Original Magnification 1000X
Radioactive Paper Point
Group II - Pulp Canal.
Figure 7: Original Magnification 1000X
Radioactive Cotton Pellet
Group IV - Pulp Chamber.
The thesis submitted by Dr. Gerald R. Heiman has been read and approved by three members of the Graduate School faculty.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with references to content, form and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Science.

May 19, 1971

Date

Signature of Advisor